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THE PHLOX MIDGE, *Hyperdiplosis Phlox Greene* and ITS INSECT ENEMIES

C. R. Neiswander

OHIO AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

SUMMARY

A new species of Cecidomyiid, described by Charles T. Greene as *Hyperdiplosis phlox,* and given the common name of phlox midge in this paper, has been causing severe injury to the terminal buds of phlox in Ohio. Associated with this insect on the phlox plant are twelve other species of insects, eight of which are also new to science. Of the 12 species, one is another Cecidomyiid that is predaceous on the phlox midge and has been described by Greene as *Lestodiplosis maculipennis.* An undescribed species of *Aphanogmus* was found to be parasitic on the predator *Lestodiplosis maculipennis.* The remaining 10 species are all parasitic on the phlox midge. These include three undescribed species of *Platygaster,* one of *Leptacis,* one of *Chrysocharoideus,* and one of *Tridymus.* An additional species, and perhaps the most abundant parasite of all, was originally identified as another new species of *Platygaster,* but was later identified as *Xestonotidea brevicornis* Fouts. Three species described previously and found to be parasitic on the phlox midge include *Leptacis pennsylvanicus* Fouts, *Zatropis catalpae* Cwfd., and *Cerato-teleia parvipennis* M. & B.

The parasites and the predators become very abundant and by late summer have greatly reduced the phlox midge population. In single collections of phlox midge larvae as high as 75 per cent have been parasitized. However, damage to phlox has not been prevented because parasitization did not become important until the phlox midge was in its second generation and much of the damage had already occurred.

The phlox midge was found to spend the winter as larvae in the soil and adults emerged in late May or early June. There were approximately five generations a year, although late in the season the generations were not distinctly separated.

The most effective control measures found were extensive soil cultivation and the application of a tobacco dust mulch to the soil surface. These measures prevented large numbers of adults from emerging from the soil.

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THE PHLOX MIDGE, HYPERDIPLOSIS PHLOX GREENE, AND ITS INSECT ENEMIES (1)

C. R. NEISWANDER

For a number of years, extensive insect injury to phlox has been observed in northeastern Ohio in estate gardens where relatively large plantings of phlox are grown for mass color. The most pronounced injury has occurred at Chagrin Falls and Canton; injured panicles have been received from Cleveland and Cincinnati; and characteristic injury has been observed repeatedly in small garden plantings in a number of other localities. During the period 1938 to 1942, when this investigation was being carried on, injury to phlox occurred in all plantings inspected in the city of Wooster. Doubtless the insect is much more widely distributed than our present records indicate because untrained gardeners are likely to overlook or ignore the injury, although to trained gardeners the damage is conspicuous and severe.

The nature of the injury consists essentially in the destruction of the terminal buds. The first evidence of injury is a slight buckling over of the terminal bud. Later the new leaves fail to develop but become crumpled and distorted and finally die. Phlox plantings have been seen in which practically all of the terminal buds have been killed. The nature of the early injury is shown by a photograph taken in an ornamental garden at Canton, Ohio, in 1939 (figure 1). A comparison of injured and uninjured phlox terminals is shown in figure 2. Later in the season when lateral shoots develop, some injury occurs in them also, but the injury to lateral buds is seldom so severe as to prevent blooming. However, as a result of the destruction of terminal buds and some injury to lateral buds, a much distorted flower panicle is produced as may be seen in a comparison of Figures 3 and 4.

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(1) The writer wishes to express appreciation to C. F. W. Muesebeck, A. B. Gahan, B. D. Burks, and Charles T. Greene of the ARS, U. S. Department of Agriculture, for the determination of species associated with this problem. He also wishes to thank B. A. Myers of the Halfred Farms staff at Chagrin Falls and W. J. Bruce of the O'Dea Estate at Canton for their helpfullness while conducting these investigations.

Fig. 1. – Phlox clump in garden showing cecidomyiid injury to terminals.

Fig. 2. – Injured phlox terminals on left. Uninjured terminals on right.

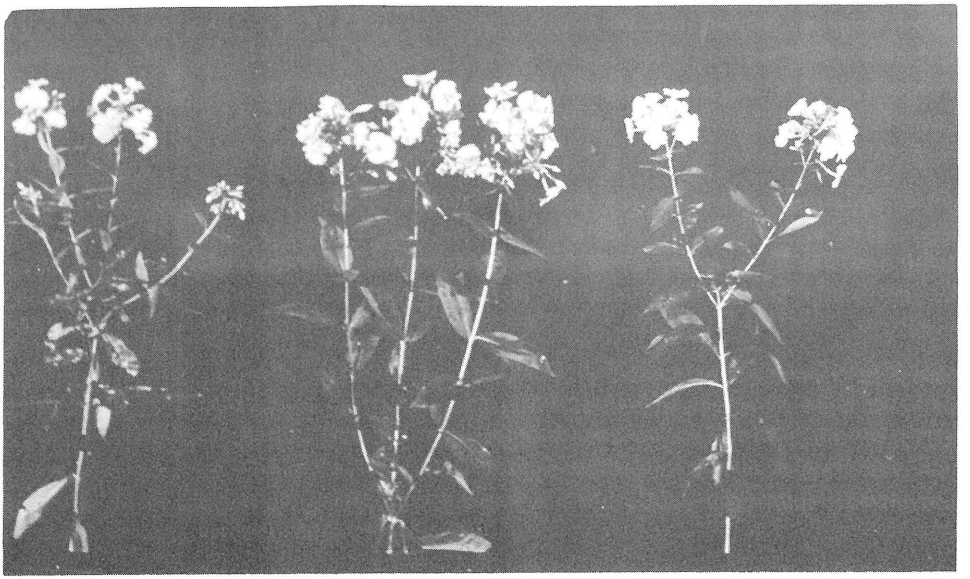

Fig. 3. – Phlox flower stalks showing the result of severe phlox midge injury.

Fig. 4. – Flower stalks of phlox with terminals only slightly injured by phlox midge.

THE PHLOX MIDGE ASSOCIATION COMPLEX

During the course of this study an extremely interesting insect association complex was found, all insect species being associated with the injury to phlox terminals. A total of 13 species were reared to adults and were submitted to the U. S. National Museum for identification. In figure 5 the relationship between the various species is shown. It is interesting to note that of the 13 associated species, 9 were reported as either new to science or unidentified at the time this investigation was undertaken and 7 are still unnamed.

The species causing the injury to phlox was found to be new to science and was eventually described by Greene (1941)as *Hyperdiplosis phlox*. This is the species that the writer has designated as the phlox midge. A second cecidomyiid which was found to be predaceous on *Hyperdiplosis phlox* was also new to science and was described by Greene (1941) as *Lestodiplosis maculipennis*. The remaining

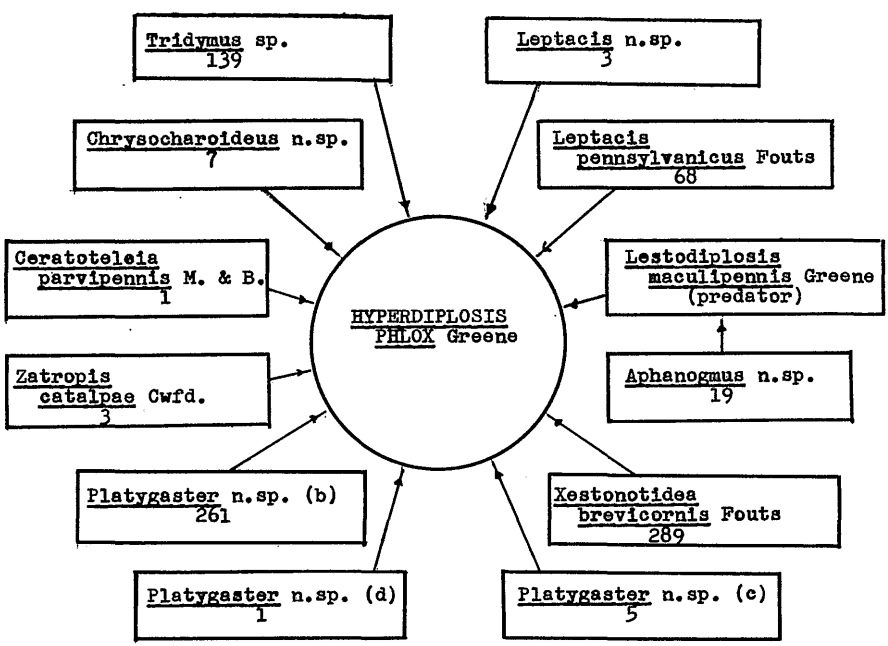

Fig. 5. – The phlox midge association complex showing the species involved and the number of adults reared of each parasitic species.

species were hymenopterous parasites of one or the other of these two cecidomyiids as indicated in the diagram. Of the 11 species of hymenopterons reared 7 are at present unidentified, most of which are probably new to science.

DESCRIPTION OF THE PHLOX MIDGE

When the leaflets that make up the terminal bud in an injured plant are pulled apart, tiny dipterous larvae may be found within the bud between the immature leaves. The larvae are so small as to be barely discernible with the naked eye. When full grown, they measure approximately 2 millimeters in length. Usually several larvae occur within a single bud and sometimes they become extremely abundant. As many as 41 larvae have been taken from a single terminal. In such instances they become masses of contiguous larvae competing for food within a small space. The general location of the larvae in the plant is shown in a diagrammatic drawing, figure 6. During the growth period the larvae are white but when full grown become slightly brownish. The body tapers sharply toward the anterior end and moderately toward the posterior end. The larvae are not very active and apparently are unable to move from one bud to another. The identifying characters of larvae and adults of *Hyperdiplosis phlox* as well as those of *Lestodiplosis maculipennis* as given by Greene are reproduced in figure 7.

SEASONAL HISTORY OF PHLOX MIDGE

Usually the phlox midge larvae can be found in phlox plantings during the first few days of June. By mid-June, they are extremely abundant and are present in the garden as late as the latter part of September or the early part of October. In studying the seasonal history, terminals were collected from the garden at intervals of a few days throughout the season. It was found that the larvae were extremely abundant at three different times in the summer. These were about June 15, July 8, and August 1, although the time varied a few days with the nature of the season. During the periods of greatest larval abundance, the average number of larvae per terminal was about 7 or 8, although individual collections have averaged as high as 14. However, it was not unusual to find as many as 20 to 30 larvae in a single terminal bud.

Considerable difficulty was experienced in rearing the insects because of their minute size. It was necessary to confine the larvae to

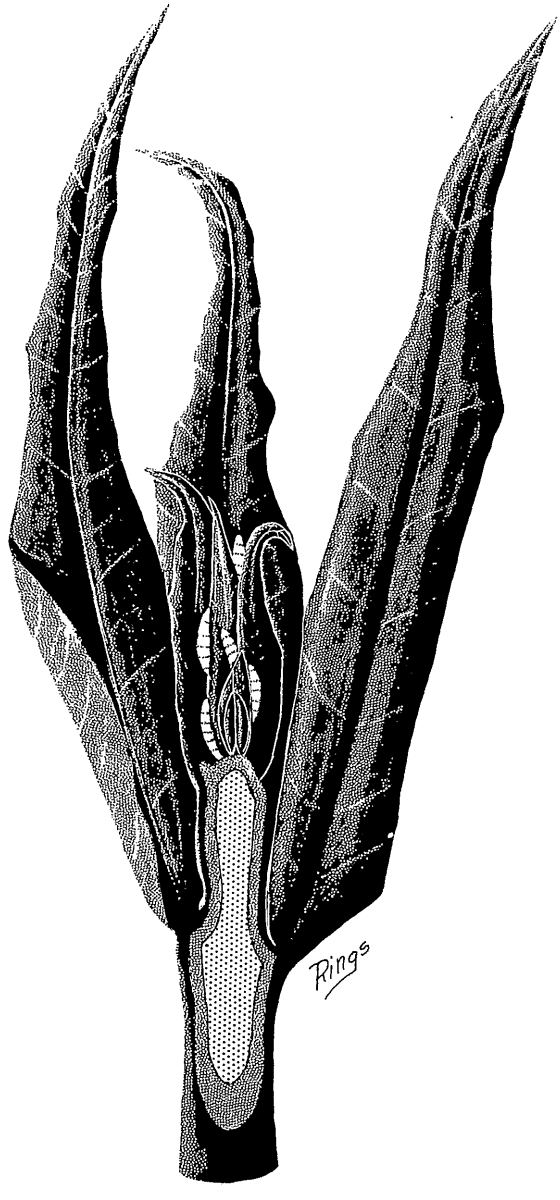

Fig. 6. – Diagrammatic drawing of sectioned phlox stem to show location of larvae in terminal bud.

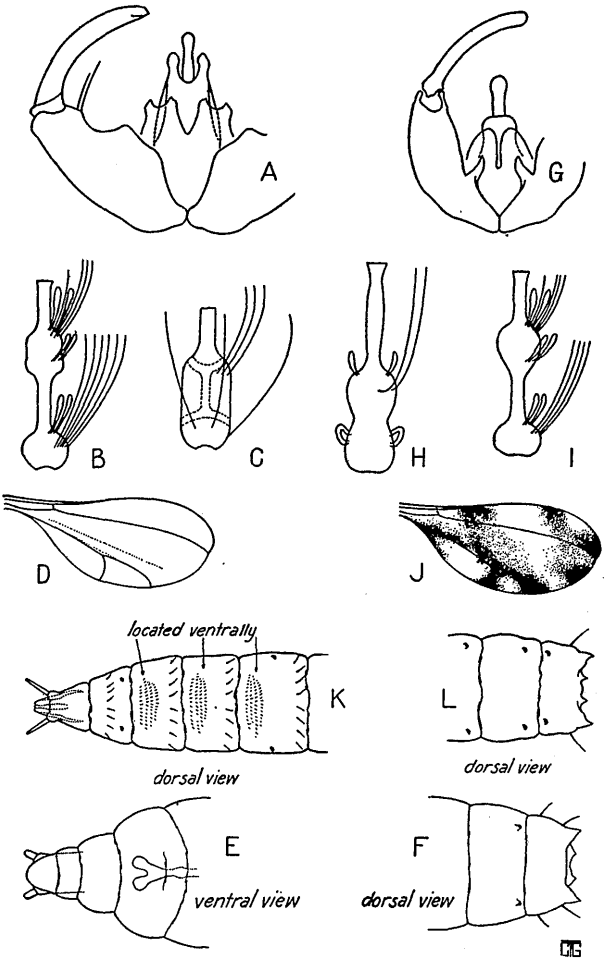

Fig. 7. – Two New Flies Reared From Phlox. – A-F, *Hyperdiplosis phlox:* **A, Male genitalia; B, fifth segment of male antenna; C, fifth segment of female antenna; D, wing of male (type); E, anteroventral view of last-instar larva; F, posterodorsal view of last-instar larva; G-L,** *Lestodiplosis maculipennis;* **G, male genitalia; H, fifth segment of female antenna; I, fifth segment of male antenna; J, wing of male (type); K, anterodorsal view of last-instar larva; L, posterodorsal view of last-instar larva.**

(Reproduced from "Two New Species of Cecidomyiid Flies from Phlox" by Charles T. Greene, 1941, Proc. U. S. Nat. Mus. Vol. 90, P. 549, by courtesy of the author and publishers).

small vials in order to keep from losing them. However, a satisfactory technique was finally developed. Large numbers of infested phlox terminals were brought to the laboratory and kept under observation in glass jars. The larvae fed readily within the terminals. As the larvae became full grown they left the terminals and started crawling over the glass container. These full-grown larvae were then placed in small glass vials containing a small amount of sterilized soil. They constructed chambers only slightly under or at the soil surface. In these chambers the larvae transformed to pupae and later to adults.

Daily records were taken of the emergence of adult cecidomyiids and the parasites. Inasmuch as collections were made at frequent intervals throughout the season, the emergence record for adults gave a fairly accurate record of the flight period of the various species and their abundance through the season. A curve of adult phlox midge emergence and total parasite emergence made from larvae collected in the garden and reared in the insectary in 1940 is shown in figure 8. Emergence records for other years were similar.

This curve indicates that there were probably five summer broods of the phlox midge. However, it is probable that both the fourth and fifth broods were not complete. At any rate, some of the larvae taken in August did not emerge until the following spring. On the other hand, a few of the larvae taken in early September emerged before cold weather stopped all development. Most phlox clumps are in full bloom by mid-August and from then on it is difficult to find developing buds in which the larvae feed. However, larvae have been taken from gardens as late as October 9.

In a study of hibernation during the winter 1940-1941, larvae that were collected in the fall which had not emerged when cold weather arrived were carried over winter in a cave. Vials containing the larvae in soil were placed in a box on a pedestal within an excavated chamber covered over with sod. In early May, the vials were removed from the chamber and stored in the insectary. Daily observations were made for adult emergence.

During the spring period, occasional larvae were seen moving about on the soil within the vials, thus indicating that they had gone through the winter as larvae. The first adult fly emergence occurred on May 27, which is near the expected emergence date from observations made in the gardens, since young larvae have always appeared during the first few days of June. Subsequent emergence occurred throughout the fore part of June. The curve of adult emergence after hibernation is shown in figure 9. It may be noted that there was a divided emergence period.

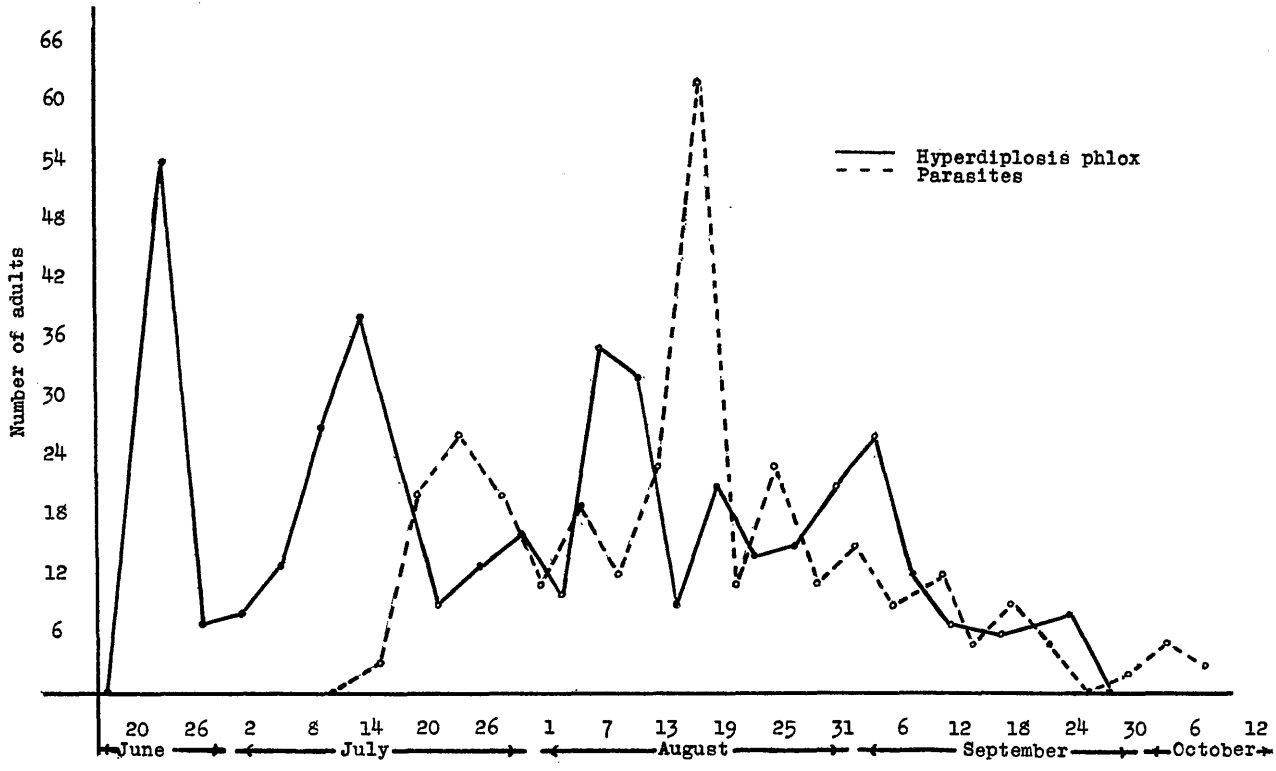

Fig. 8.—Emergence curve for *Hyperdiplosis phlox* and its parasites during the season of 1940 at Wooster.

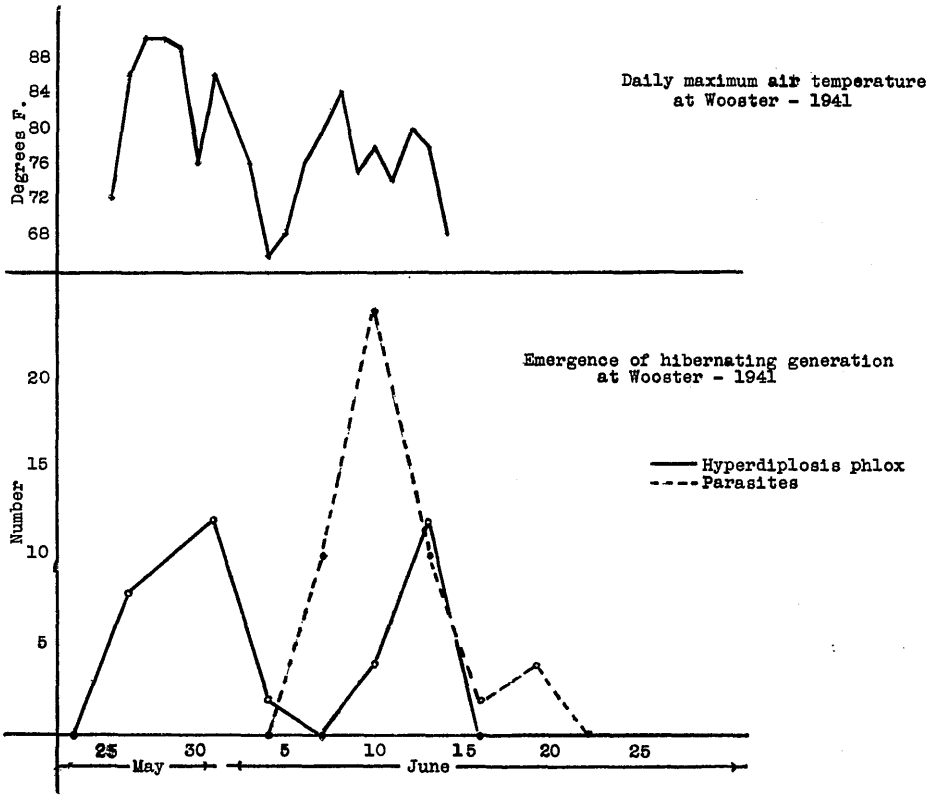

Fig. 9.— Spring emergence period for the hibernating generation of the phlox midge and its parasites in 1941.

The greatest emergence occurred during the last few days of May and the first few days of June; however, a number of flies emerged as late as June 15. A curve of maximum daily air temperatures at Wooster is also shown in figure 9. It may be seen that a cold period occurred between June 1 and June 6. Since this period is also the one in which no adult emergence occurred, the temperature was undoubtedly responsible for the divided emergence period.

It may be noted from figure 9 that total parasite emergence from hiberating phlox midge larvae was about 10 days later than that of the host. This again is in accordance with field observations.

INSECTARY REARINGS

In order to observe for egg deposition, terminals of phlox with the stems inserted in water in small vials were placed in rearing cages containing a great many newly emerged adults. The mass rearing cages were gallon battery jars containing a layer of damp soil and covered with cheesecloth. The phlox terminals were introduced in the cage at 2:00 p.m. on June 23, 1938, and were removed at 4:00 p.m. of the same date so that all eggs occurring on the terminals would have been deposited during this 2-hour period. When the phlox terminals were removed, it was found that over 100 eggs had been deposited. The eggs are elongate, tapering slightly at one end. They occurred at various places on the terminal buds. Many were on the edge of a leaflet, but others were along the midrib on both the ventral and dorsal surfaces.

The first eggs were observed to hatch at 4:00 p.m. on June 25, 50 hours after oviposition. By 6:00 p.m. practically all had hatched. Additional eggs taken out of the oviposition chamber on June 25 were all hatched by June 28. Hence, the length of the incubation period as determined by these observations was from 2 to 3 days.

Thirty-five individuals were reared from the egg to the adult stage. The average time required for the entire life cycle for these 35 individuals was 25 days, with a minimum of 19 and a maximum of 33. The duration of the pupal period was not determined, but an average of 10 to 12 days elapsed between the time the larvae entered the soil and the adults emerged. The life history curve, Figure 8, indicates an interval of about 25 days between emergence peaks for adults that were collected as larvae in the field and reared in the laboratory.

THE CECIDOMYIID PREDATOR, LESTODIPLOSIS MACULIPENNIS GREENE

The larva of the cecidomyiid predator is somewhat yellowish in color when small but becomes orange to reddish as it approaches the full grown stage. In life it appears slightly larger than *Hyperdiplosis phlox*. The predator can be distinguished quite readily from the injurious form not only by the color but also by its shape and method of locomotion. It moves rapidly about over the foilage in apparent search for food material. It attacks its prey by inserting its pointed mouth parts into the host and sucking out the body fluids leaving a collapsed body shell as remains. The body of the prey may be pierced at almost any point. When the attack is first made there is a violent struggle on the part of the phlox midge larva, but it soon becomes quiescent and lies as if dead. Small larval predators have been observed to kill host larvae much larger than themselves.

The life cycle of the predator is somewhat similar to that of the phytophagous form, although the number of cycles per year has not been determined. When the larvae are full grown, they spin a white silken cocoon which can be found quite readily in or on the soil. In cages this species does not always enter the soil for pupation. It does not use soil particles in constructing the cocoon as does the phytophagous form. The insect has been carried through the winter in cocoons amid particles of soil and has emerged in the spring about 10 days later than the phlox midge.

The predator is of considerable importance in reducing the numbers of the phlox midge. In July when the predators are active and when phlox midge larvae are abundant in the growing tips of phlox, it is not unusual to see 3 or 4 collapsed bodies in a single bud. Unfortunately, however, the predaceous form does not appear in gardens until much of the damage is done. It seldom is present to attack the first generation of its host, but from the second generation on, it becomes of increasing importance. Late in the season it frequently becomes so abundant that there is probably an insufficient number of the phlox midge larvae present to serve the food requirements of the predator population. In come collections taken late in the season, the predator has been almost as numerous as the phytophagous form. The relative abundance of the predator and its host in phlox gardens at intervals through the summer of 1940 is shown in Table 1.

Table 1. Ratio of abundance of larvae of *Lestodiplosis maculipennis* and *Hyperdiplosis phlox* in collections made in gardens at Canton and Chagrin Falls, Ohio, 1940.

Collection date	Larvae in twigs collected		Ratio between predator and host
	Hyperdiplosis phlox	Lestodiplosis maculipennis	
June 11	435	0	1 : Inf.
July 10	237	16	1 : 15
Aug. 9	208	21	1 : 10
Sept. 4	53	8	1 : 7

A hymenopterous parasite reared from *Lestodiplosis maculipennis* was identified by Muesebeck as being an unnamed species of the genus *Aphanogmus*. Muesebeck stated that very little is known about the food habits of members of this genus. It is interesting to note that in 1942 the writer reared another species of this genus from *Mycodiplosis acarivora* (Felt), a cecidomyiid predaceous on the two-spotted spider mite, *Tetranychus telarius* (L.). In a recent letter Muesebeck has identified the *Mycodiplosis acarivora* parasite as *Aphanogmus floridanus* Ashm.

PARASITES

Of the 13 insect species reported here as included in the phlox midge association complex the newly described cecidomyiid, *Hyperdiplosis phlox* Greene, is the only species that is directly injurious to phlox. The other new cecidomyiid, *Lestodiplosis* maculipennis Greene, is predaceous on *Hyperdiplosis phlox*. The *Hymenopteron, Aphanogmus* sp., is parasitic on *Lestodiplosis maculipennis*. The remaining 10 species are all parasitic on *Hyperdiplosis phlox*.

The two parasites taken most frequently were *Xestonotidea brevicornis* Fouts and *Platygaster* n. sp. (b). These two species were nearly equal in number and accounted for about 70 per cent of the total parasitism. The specimens listed as *Xestonotidea brevicornis* Fouts were originally identified by Muesebeck as an undescribed species of *Platygaster* and listed in correspondence as *Platygaster* n. sp. (a). More recently the identification has changed to *Xestonotidea brevicornis* Fouts.

Other fairly common parasites include *Leptacis pennsylvanicus* Fouts and *Tridymus* sp. both of which occurred frequently. Parasitic species that occurred in smaller number include *Platygaster* n. sp. (c), *Platygaster* n. sp. (d), *Chrysocharoideus* n. sp., *Zatropis catalpae* Cwdf., *Leptacis* n. sp. and *Ceratoteleia parvipennis* M. & B.

Zatropis catalpae was found by Houser to be parasitic on the Catalpa midge, *Itonida catalpae* Comstock, in Ohio. Concerning *Ceratoteleia parvipennis*, Muesebeck stated in a letter that the species was "not previously represented in the national collection. It ought to be parasitic in eggs of Orthoptera".

The parasites of phlox midge become extremely abundant in July. Individual collections of phlox midge larvae have been taken when parasitization from all species has been as great as 76 per cent. Unfortunately, the parasites, like the predator, do not become effective until the phlox midge is in its second generation, when much of the damage has already been done.

While rearing the phlox midge for life history studies, complete emergence data were also taken on all parasites obtained. The per cent of parasitization that occurred at different dates through the summer of 1940 is shown in Table 2. Similar results were obtained in 1939 and in 1941. The per cent parasitization record is based on the number of adults of the phlox midge and of its parasites that were reared from collections made throughout the season. The data represent total parasitization from all parasites reared.

Table 2. Per cent parasitization of *Hyperdiplosis phlox* from rearings made at intervals through the season of 1940 at Canton and Chagrin Falls, Ohio.

Collection date	Adults reared		Percent parasitization
	Hyperdiplosis phlox	Total parasites	
June 11	104	0	0
June 18	26	7	21.2
June 25	48	42	46.7
July 18	22	43	66.2
July 31	53	36	40.4
August 14	33	13	28.3
August 28	24	6	20.0
Sept. 18	12	0	0

Parasites were reared also from hibernated phlox midge larvae. As shown in Figure 8, their emergence period was somewhat later than that of the midge adults. This behavior corresponds closely with field observations inasmuch as rearings from field collected material made over a period of 3 years indicated that but little parasitization occurs on the first phlox midge generation.

EXPERIMENTS IN CONTROL

Ornamental gardens do not lend themselves well to experiments in insecticidal control. Phlox plantings were made at Wooster but midge infestation did not develop in cultivated plots. Phlox plants grown by gardeners for stock plants in the field have also failed to develop severe infestations although light infestations have been noted. Probably both the spacing of the plants and the cultivation have tended to prevent infestations in places other than ornamental gardens where conditions are fairly humid and the insects at the soil surface are protected by shade. By marking off the garden in sections and spraying different sections with different materials a semi-demonstration experiment was set up. Spray materials including nicotine sulphate, pyrethrum, an aliphatic thiocyanate, and a summer oil were applied at weekly intervals but none were highly effective in preventing injury. Laboratory experiments using infested phlox terminals gave from 40 per cent to 60 per cent mortality of midge larvae with the different materials used. Lack of effective insecticidal control of the larvae within the phlox buds may have been due in part to inability to reach them with the insecticides since they were enclosed entirely within unopened buds.

When it was found that the larvae entered the soil before pupation, experiments in soil treatment were tried. Full-grown larvae were placed in vials containing soil and were permitted to enter the soil to spin their cocoons. When all of the larvae had become concealed, treatments were applied to the soil surface. In one such experiment a tobacco dust mulch containing 1 per cent nicotine was placed over the infested soil to a depth of one-sixteenth of an inch. In another treatment of the same experiment, additional sterilized soil was applied to the soil surface to a depth of one-eighth inch. Approximately 50 larvae were used in each unit of the test and all treatments were replicated five times. Following these treatments a record was kept of the subsequent emergence of adults of both the phlox midge and its parasites. The results of this test are shown in Tables 3 and 4.

Table 3. Phlox midge emergence from soil after control experiment using soil and tobacco dust mulches – 1941.

Treatments	Phlox midge adults recovered					
	R1[1]	R2	R3	R4	R5	Mean
Soil – 1/8 inch	1	1	0	1	0	.6
Tobacco dust 1/16 inch	0	0	0	0	0	.0
Check – Not treated	22	14	18	12	11	15.4

[1]R1, R2, R3--------refer to numbers of replicate.

As shown in Tables 3 and 4, a 1/8 inch layer of soil and 1/16 inch layer of a tobacco dust mulch containing 1 per cent nicotine were both very effective in preventing both midge and parasite emergence. Only 3.8 per cent of the Cecidomyiids were able to emerge through 1/8 inch of soil whereas 20 per cent of the less fragile parasites emerged from the same treatment. Subsequent experiments showed that a 3 per cent nicotine dust in lime applied in only a sufficient quantity to make the soil surface white was as effective as the tobacco dust mulch. Dichloroethyl ether used at the rate of 8 cc. per gallon of water applied at the rate of 15 gallons per 100 square feet gave a 50 per cent reduction in phlox midge emergence.

Table 4. Parasite emergence from soil after control experiment using soil and tobacco dust mulches – 1941.

Treatments	Parasite adults recovered					
	R1[1]	R2	R3	R4	R5	Mean
Soil – 1/8 inch	1	0	1	2	2	1.2
Tobacco dust 1/16 inch	0	1	0	0	0	.2
Check – Not treated	6	4	6	7	7	6.0

[1]R1, R2, R3 ---- refer to numbers of replicate.

As a result of these investigations the control recommendations made have been extensive soil cultivation in the spring followed by the application of a tobacco dust mulch to the soil around the plants, the object being to prevent the emergence of adults from the ground. Accordingly, in 1941, the gardener on the O'Dea Estate in Canton spaded up his phlox garden, reset all phlox clumps, and applied a tobacco dust mulch. During the succeeding season no damage occurred, although the phlox in a neighboring garden was severely injured. In like manner, extensive culti-

vation around phlox plantings in the Halfred Farms garden at Chagrin Falls in 1941 also resulted in greatly reduced damage.

After the introduction of the many new agricultural chemicals in the late 1940s, estate gardeners have informed the writer that sprays such as DDT applied in early June have given effective control of the insect. The writer has not had an opportunity to evaluate the new insecticides for this purpose.

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Greene, Charles T. 1941. Two new species of Cecidomyiid flies from phlox. Proc. U. S. Nat. Mus. Vol. 90, No. 3120, pp. 547-551.

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